Storage of Rice. XVI.

Storage of Rice in Concrete Silos for Five Years.

By

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I. Introduction.

After repeated experiments the authors[1)–4)] have concluded that rice can be safely preserved, if it is thoroughly dried and stored in tin containers. In the authors' opinion concrete silos can also be used for storage of large amounts of rice. However silos are not used at all in Japan for the storage of rice and no other experiment than this present one has ever been carried out. In February 1931 the authors stored rice of 1930 crop in 2 concrete silos and preserved it till November 1935 during five years. The storage was quite successful. In the present paper the results will be described in detail.

II. Method of Storage Experiment.

The concrete silos used for the storage experiment are cylindrical, internal measurements 3 meters high and one meter in diameter and have the capacity of 10 koku *. The wall is 15 cm thick. One of the silos was filled with hulled rice and the other with unhulled rice. The silos were sealed hermetically. (Photo. XXV, and XXVI.)

A tin container of the half capacity of the silos was used for comparison with the silos, containing the same kind of hulled rice.

The material used in this experiment was "Asahi" variety and the hulled rice was dried to a moisture content of 11.6% and the unhulled rice to that of 10.8%.

At the beginning of the storage the general properties of rice, physical, chemical and biological, were studied. Since then in February 1934, just three years and three months after harvest and in November 1935, five years after

* One koku=0.18039 Kiloliter.

harvest the whole rice was taken out of both the silos and the tin container and a comparison of the change of the properties of rice during storage of five years was studied thoroughly.

III. Results of the Storage Experiments.

Owing to its very smooth surface and a great volume weight, the hulled rice was heavily pressed together in the lower part of the silos and it hardly flowed out when opened. It was quite different in this respect from unhulled rice, wheat, barley, maize etc. It was found that three meters must be the maximum height of silos for hulled rice. The present material was compressed heavily on the bottom of the silos, however it was not damaged at all, because it was thoroughly dried to a moisture content of 11.6%.

1. *Temperature of Rice.*

From time to time, the temperature of rice in silos was observed and it was found that the rice never became heated. It really shows that the rice was stored in a good condition.

2. *Colour and Smell of Rice.*

Three years after harvest the condition of the rice was once investigated and two years later the investigation was repeated again. It was found that the hulled rice in the silos was only slightly coloured to light brown, if compared with new rice. Its smell was quite good. No real change of the quality had occured.

The unhulled rice in silos became a little brown five years after harvest. Its kernels were also faintly brown coloured. However, the quality was quite good and its odour normal. There was hardly any differece of quality between the two lots of rice, namely the hulled and the unhulled rice.

The hulled rice in a tin-container was perfectly preserved. Its colour and smell was quite like new rice.

The general qualities of the three lots of rice, although its storage conditions were different, were always almost as good as new rice, so that nobody would notice that the rice was five years old.

3. *Insects.*

The rice in the silos was kept quite free from insects. The tin container however, was accidentaly a little damaged after three years, and *Calandra oryzae* entered and thrived therein, but the rice was not damaged at all. By the fumigation with carbon disulphide the insects were killed, but the germination power of rice was lost thereby.

4. *Moisture Content of Rice.*

At the beginning of the experiment, and three and five years thereafter respectively, the moisture content of rice was determined, and the results shown in Table 1 were obtained.

Table 1.
Moisture Content of Stored Rice.

Materials	Initial moisture	Moisture in February 1934	Moisture in November 1935
	%	%	%
Hulled rice in the silo · · ·	11.6	13.4	12.9
Unhulled rice in the silo (determined by hulled rice)	11.6	13.3	13.5
Hulled rice in the tin container	11.6	12.1	12.0

The table shows that, during the first three years the moisture content of the rice in silos increased about 1.8%, owing to the absorption of moisture from the silo wall. Since then, the moisture content did not increase. It suggests that a new silo must not be used until after it is thoroughly dried. If the silos are quite dry, the rice can be preserved without any increase of the moisture content. The moisture content of rice in the tin container should be always invariable during the time of storage, notwithstanding the increase of 0.5% shown in Table 1. This must be due to an experimental error. In comparison of the unhulled rice with the hulled rice, it is certain that the husks (chaffs or glumes) do not protect kernels from moisture absorption.

5. *Weight of 1000 Grains of Rice.*

Regarding the weight of 1000 grains, it was observed that no remarkable variation occured during storage as Table 2 shows.

Table 2.
Weight of 1000 grains.

Lots of rice	Initial weight of 1000 grains	Weight in February 1934	Weight in November 1935	Difference between the initial and final weight
	g	g	g	g
Hulled rice in the silo · ·	24.599	24.582	24.598	−0.001
Unhulled rice in the silo (determined by hulled rice)	24.477	24.717	24.727	+0.250
Hulled rice in the tin container	24.505	24.330	24.276	−0.229

6. *Volume-Weight of Rice.*

The volume weight of the rice decreased during storage in silos, owing particularly to the increase of moisture. The volume weight of rice in the tin container decreased a little too, but this not certain, because in the earlier experiments[1),3)] the authors observed that, contrary to the result of the present experiment, the volume weight of the hulled rice in a tin container increased a little.

The weight per hectolitre of rice determined in the beginning, after three years and in the end of storage, is given respectively in Table 3.

Table 3.

Volume-Weight of Rice.

Lots of rice	Initial volume-weight	Volume-weight in February 1934	Volume-weight in November 1935	Difference between the initial and final weight
	kg	kg	kg	kg
Hulled rice in the silo · ·	86.52	84.67	84.46	−2.06
Unhulled rice in the silo	61.11	62.82	62.33	+1.22
Unhulled rice in the silo, but determined after hulling	86.52	83.91	84.06	−2.46
Hulled rice in the tin container	86.55	85.77	85.23	−1.32

In contrast to the hulled rice, the volume weight of the unhulled rice in the silo increased during the time of storage, being caused chiefly by the absorption of moisture and owing to greater compactness through loss of original roughness on the surface of husks. It is quite different from the case of hulled rice.

7. *Hardness of Rice Kernels.*

The hardness of the rice kernels in the silos decreased slightly, being affected by the moisture absorption from the silo wall. In the case of the tin container, it was quite different, because the hardness of rice usually increases by ageing. The two kinds of the hardness, i. e. the resistance to breaking and to crushing are determined. The results are given in Table 4.

Tabel 4.

Hardness of Rice Kernels.

Hardness of rice kernels		Initial hardness	Hardness in Feb. 1934	Hardness in Nov. 1935	Difference between the initial and final hardness
		kg	kg	kg	kg
Hulled rice in the silo	resistance to breaking	10.18	9.52	9.77	−0.41
	„ „ crushing	10.98	10.06	10.36	−0.62
Unhulled rice in the silo (determined after hulling)	resistance to breaking	10.20	8.89	9.37	−0.83
	„ „ crushing	10.81	9.88	10.33	−0.48
Hulled rice in the tin container	resistance to breaking	10.14	10.90	11.09.	+0.95
	„ „ crushing	11.07	11.15	12.35	+1.28

8. *Viscosity of Rice Paste.*

The viscosity of rice paste of the stored materials was tested by STORMER's viscosimeter. The paste had the density of 5% (water 100cc. : rice powder 5 g) with the temperature of 40°C. Taking the viscosity of water of 40°C. as an unit, the viscosity of the paste was determined. The results are shown in Table 5.

Table 5.

Viscosity of Rice Paste.

Materials	Initial viscosity	Viscosity in Feb. 1934	Viscosity in Nov. 1935	Difference between the initial and final viscosity
Hulled rice in the silo	1.62	1.63	1.63	+0.01
Unhulled rice in the silo	16.2	1.60	1.61	−0.01
Hulled rice in the tin container	16.2	1.63	1.63	+0.01

According to Table 5, the viscosity of rice paste was scarcely changed during storage of five years.

9. *Kamabue (Expansion) of Boiled Rice.*

The percentage of increase in volume of boiled rice form the original volume of white rice is called "Kamabue". Kamabue of the stored rice was investigated and the following results were obtained, as shown in Table 6.

Table 6.

Kamabue of the stored Rice.

Materials	Initial Kamabue	Kamabue in Feb. 1934	Kamabue in Nov. 1935	Difference between the initial and final Kamabue
	%	%	%	%
Hulled rice in the silo	131.3	130.1	130.2	−1.1
Unhulled rice in the silo	131.3	133.2	131.5	+0.2
Hulled rice in the tin container	131.3	131.8	131.2	−0.1

According to Table 6, "Kamabue" of the rice stored five years scarcely changed during storage.

10. *Water-absorbing and Swelling Capacity of Rice.*

The water-absorbing and swelling capacity of the stored rice was determined by soaking: 50 gs. of rice from each material in water at 25° to 28°C. for 48 hours and noting the percentage of increase in weight and volume. The results are shown in Table 7.

(See Table 7 on next page).

According to Table 7, the water-absorbing and swelling capacity of the rice in the silos decreased in the first three years in a great degree, but after that only slightly. This is owing to the increase of moisture as well as the ageing of kernels. There is, however no distinct difference between the stored hulled and unhulled rice. The hulled rice in the tin container decreased its capacity in the first three years, but in a smaller degree than the rice in silos, owing principally to the ageing, but not to the moisture absorption. The authors always

found that some decrease of the water absorbing and swelling capacity caused by the ageing is inevitable, neverthless the rice is preserved in a perfectly good condition.

Table 7.

Water-absorbing and Swelling Capacity of Rice.

Materials	Determined items	Initial capacity	Capacity in Feb. 1934	Capacity in Nov. 1935	Difference between the initial and final capacities
		%	%	%	%
Hulled rice in the silo	Water-absorbing capacity	28.03	23.02	22.97	−5.06
	Swelling capacity	38.10	30.76	30.69	−7.41
Unhulled rice in the silo (determined by hulled rice)	Water-absorbing capacity	28.02	24.28	22.94	−5.08
	Swelling capacity	38.10	32.21	30.24	−7.86
Hulled rice in the tin container	Water-absorbing capacity	28.03	25.83	25.51	−2.52
	Swelling capacity	38.20	34.75	34.55	−3.65

11. *Polishing Loss of Rice.*

The material lost by polishing was determined by slight pounding of the rice in a mortar. The results are as shown in Table 8.

Table 8.

Material lost by Polishing.

Materials	Initial polishing loss*	Polishing Loss in Feb. 1934	Polishing Loss in Nov. 1935	Difference between the initial and final polishing loss
	%	%	%	%
Hulled rice in the silo . .	7.27	7.71	8.13	+0.86
Unhulled rice in the silo .	7.20	7.83	8.84	+1.64
Hulled rice in the tin container	7.27	7.69	8.04	+0.77

* In the beginning of storage.

According to Table 8, the polishing loss of the lots of rice increased very slightly with the length of time of storage. But, this fact is not at all certain, because the determination of polishing loss cannot be carried out with exactitude. In an earlier experiment[1] it was shown that, contrary to the above results the material lost by polishing the rice which had been stored in tin vessels, air-tight or with carbon dioxide, decreased with the length of time of storage. In the present experiment hardly there can be any difference between the hulled rice in the silo and in the tin container. The polishing loss of the unhulled rice in the silo was a little larger than that of the hulled rice.

12. *Germination of Rice.*

The germination power of the rice in the silos, hulled as well as unhulled rice, was lost almost entirely during the first three years, because the rice was not dry enough to keep its vitality for a long time, owing to absorbing moisture from the silo wall. In Okayama Prefecture rice must be dried to a moisture content of less than 13% for the preservation of germination power[3]. Three years after the storage the moisture of rice increased to 13.3%.

By storage in the tin container, the germination power of rice was kept to 99.7% three years after the storage, the moisture content being 12.1%. This fact coincides with that given in the earlier reports[2),5)].

Table 9.

Germination Power of Rice.

Lots of Rice	Germination power	
	Initial	After three years
	%	%
Hulled rice in the silo	99.3	3.9
Unhulled rice in the silo	99.3	0
Hulled rice in the tin container	99.3	97.7

If the silo wall is quite dry, then the moisture content of the rice stored therein never increases, the germination power will be as well retained as the rice in the tin container. According to Table 9, it is shown that husks of rice have no effect upon the preservation of germination power, not at all protecting the rice from absorption of moisture.

13. *Analyses of Rice.*

The lots of rice stored were analysed at the beginning of the storage, as well as three years and five years after harvest. The analytical data are shown in Table 10.

Table 10.

Composition of Rice.

In the dry substance.

Composition	Ash			Crude Fiber			Crude Protein			Fat			Starch		
Date	Feb. 1931	Feb. 1934	Nov. 1935	Feb. 1931	Feb. 1934	Nov. 1935	Feb. 1931	Feb. 1934	Nov. 1935	Feb 1931	Feb. 1934	Nov. 1935	Feb. 1931	Feb. 1934	Nov. 1935
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Hulled rice in the silo	1.22	1.22	1.22	1.35	1.41	1.47	7.69	7.64	7.60	2.56	2.57	2.59	75.34	75.52	75.70
Unhulled rice in the silo	1.22	1.25	1.20	1.35	1.46	1.56	7.69	7.61	7.61	2.56	2.57	2.57	75.34	75.14	75.17
Hulled rice in the tin container	1.22	1.21	1.22	1.35	1.32	1.35	7.69	7.60	7.60	2.56	2.45	2.59	75.34	75.37	75.32

The fact brought out in the above data is that no remarkable chemical change occured during five years.

14. *Taste of the Boiled Rice.*

Testing the taste of the boiled rice it was determined that no noticeable deterioration occured during five years storage. If the ideal taste of rice is set to 10 points, then that of the five years old rice may be estimated as follows. For comparison with the old rice, a new white polished rice was used for tests.

Hulled rice in the silo	5 years old	8.2
Unhulled rice in the silo		7.5
Hulled rice in the tin container		8.0
New rice from a market		8.5

The rice was sent to many people to test the taste, but they did not realize that the rice was really 5 years old. The authors believe that from the point of taste the storage of rice in silos was successful.

15. *Total Volume of Rice.*

The total volume of rice stored remained constant, but that of the unhulled rice in the silo decreased, through the surface of the husks becoming less rough, caused by the mechanical treatment of throwing in and drawing out the rice.

Table 11.
Total Volume of Rice.

Lots of rice	Initial volume, Feb. 1931	Final volume, Nov. 1935
	koku	koku
Hulled rice in the silo	9.73	9.74
Unhulled rice in the silo	8.93	8.77
Hulled rice in the tin container	4.82	4.81

16. *Vitamin-B_1 in Rice.*

In June 1934, and again in June 1936, the content of vitamin-B_1 in the stored rice was respectively determined. As experimental animals young White Leghorn fowls were used. By feeding the fowls with 25% of stored rice and 75% of white polished rice, the latent period of beri-beri illness was determined and the comparative value of vitamin-B_1 content in the samples of rice three and five years after harvest respectively calculated. The results are given in Table 12. As controls a new rice and a cleaned polished rice were used.

According to Table 12 the vitamin-B_1 in the hulled rice in the silo was almost perfectly preserved during five years, as for the unhulled rice in the silo its content slightly decreased. In the hulled rice in the tin container it did not decrease at all even after the lapse of 5 years from harvest, as reported in the earlier publications[2),3)]. The slight difference of the vitamin-B_1 content between the rice in the silo and that in the tin container must be caused by the difference of moisture content in the rice as reported in the earlier paper[3)]. If the silo wall is perfectly dried, then the vitamin-B_1 would be as perfectly preserved as in the tin container.

Table 12.

Results of Feeding Experiment of Fowls.

Materials	Determined in June 1934		Determined in June 1936	
	Latent period of beri-beri illness	Comparative content of vitamin-B_1	Latent period of beri-beri illness	Comparative content of vitamin-B_1
	days		days	
Hulled rice in the silo	25.3	100	21.3	95.1
Unhulled rice in the silo	22.0	94.7	16.0	72.1
Hulled rice in the tin container	29.5	105.7	23.3	100
New rice (control)	25.0	100	23.0	100
Polished white rice	6.3	0	9	0

IV. Discussion.

The concrete wall of the silos not having first been completedly dried out, the moisture content of rice therein slightly increased and its germination power was lost with the lapse of time. Its colour became slightly light brown. But, from the practical point of view, the storage of rice in silos was a success. The taste of the boiled rice was very good. If the silos are so thoroughly dried, that the moisture of rice therein never increases, the rice would be more perfectly preserved. In the present experiment of five years storage no chemical change occured and vitamin-B_1 was well preserved.

In comparison of the unhulled rice with the hulled rice, it was found that the former is never more advantageous than the latter. In regard to the germination power, the taste and the vitamin-B_1 content it was observed that the unhulled rice was somewhat inferior to the hulled rice. Moreover, the unhulled rice needs twice the space of the hulled rice. It is correct therefore to encourage the storage of hulled rice rather than the unhulled rice in a silo.

For the storage of rice in a silo the following points must be taken into consideration:—

a. Hulled rice shall be stored instead of unhulled rice.

b. The rice must be dried to a moisture content of 12% in Okayama-Prefecture.

c. The silo wall must be completely dried; the height of the silo must not exceed three meters and if necessary the width may be increased.

d. As it is necessary for the rice to be quite free from insects before storage, the storage must be begun in the winter, soon after its harvest.

e. The silo must be sealed airtight, quite waterproof and protected from the sunshine as well as from rain.

In conclusion it may be said that the present experiment concerning the storage of rice in silos was successful. It was clearly demonstrated that, if the hulled rice is thoroughly dried and hermetically sealed in silos, the rice can be preserved in safety for a period of five years or even longer without any distinct change in its qualities.

V. Summary.

1. In February 1931 the authors stored two lots of rice of the 1930 crop, namely hulled and unhulled rice in two concrete silos and preserved it till November 1935, that is a period of five years. The silos were sealed hermetically. As a control the same kind of hulled rice was preserved hermetically sealed in a tin container. Having studied after three and five years the qualities of the stored rice, the effect of concrete silos upon the storage of rice was determined.
2. After five years the hulled rice as well as the unhulled rice became slightly brownish, but no deterioration of general qualities was observed. Its smell was good. The rice in the tin container was also quite good in colour and smell.
3. Owing to the underdried silo wall, the moisture content of rice increased in the amount of 1.8%, and this also caused the loss of germination power and a slight decrease of volume weight as well as hardness of the kernels and a slight increase of polishing loss. The silos must be therefore thoroughly dried before use.
4. The viscosity of rice paste, "Kamabue" of boiled rice, the chemical composition, the vitamin-B_1 content, its flavour when boiled, and the total bulk of rice in the silos etc, all were but slightly affected by this storage during five years. These facts show that the rice remained in a good condition.
5. It was found that some decrease of the water absorbing and swelling capacity caused by the ageing is unavoidable, neverthless the rice was preserved in a perfectly good condition.
6. The present experiment about the storage of rice in concrete silos was a success. If the hulled rice is thoroughly dried and hermetically sealed in dry concrete silos, the rice can be preserved in safety during five years or even longer.

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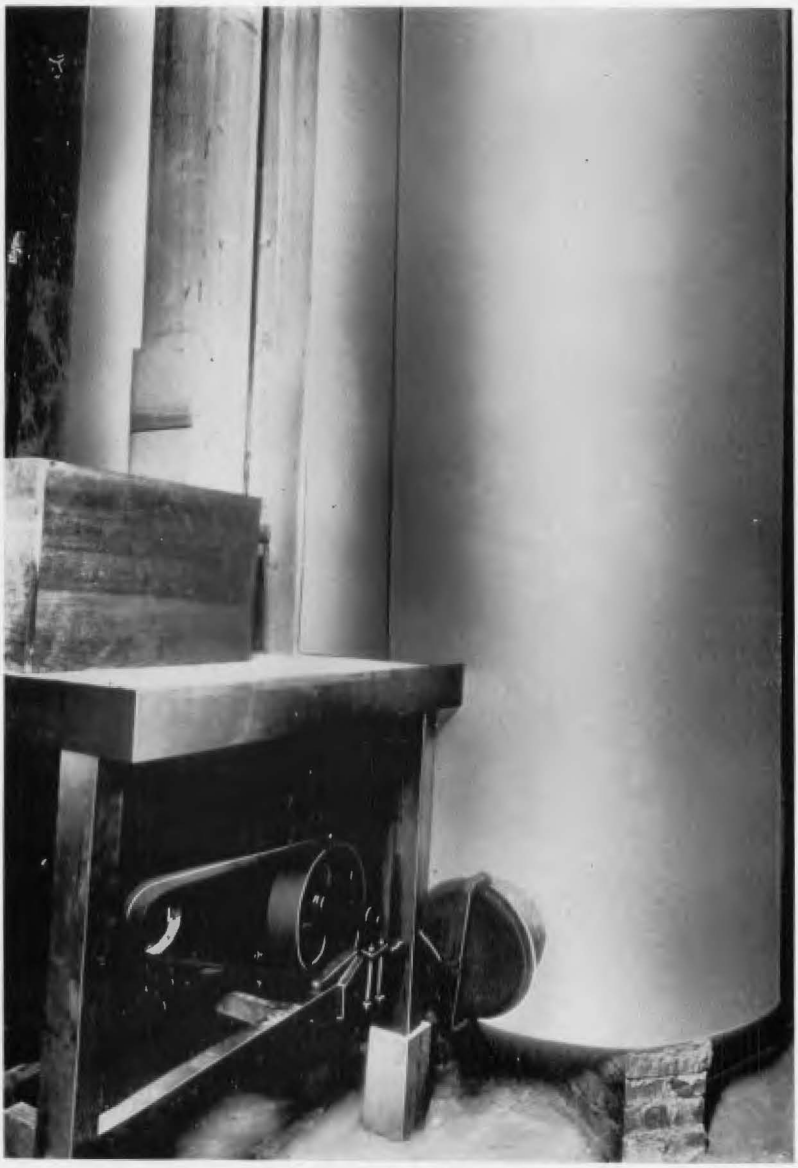

Photo. 1. Concrete silos specially constructed for the storage experiment of rice.

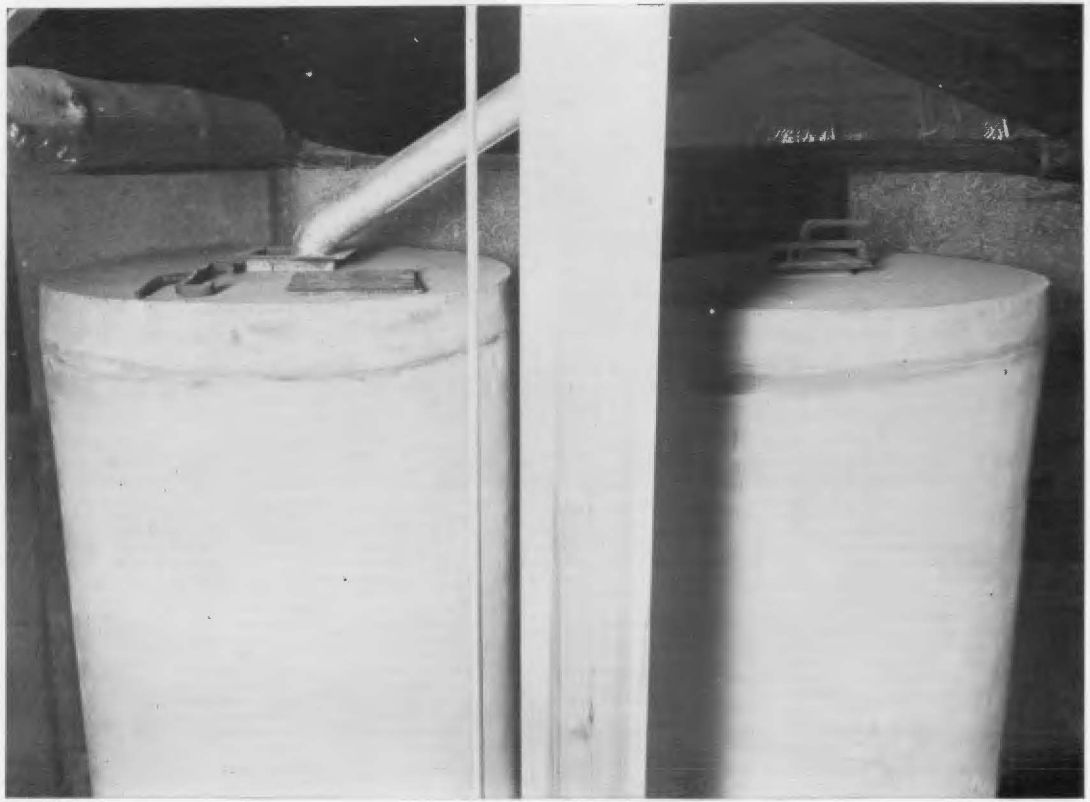

Photo. 2. Upper part of the silos.